LIQUID CRYSTAL DISPLAY DEVICE

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to a liquid crystal display device, and more particularly to a color liquid crystal display device which is displayed based on a so-called field sequential method.

2. DESCRIPTION OF THE RELATED ART

A color liquid crystal display device adopting a field sequential method is a display device which is configured to time-sequentially change over lights which pass through each pixel one after another among, for example, a red light, a green light and a blue light and, at the same time, to supply video signals for red, green and blue to respective pixels at the timing of changing over the lights.

Accordingly, although a viewer of the color liquid crystal display device receives the respective red, green and blue lights on which the pixel information is carried respectively in a time-sequentially separated state, the viewer perceives the lights in a mixed color state.

Here, such a color liquid crystal display device requires a light source which is capable of irradiating the respective red, green and blue lights. Accordingly, the color liquid crystal display device is configured such that when driving of

the light source is stopped and the color liquid crystal display device is driven using an ambient light (a white light) such as sun beams, a color display cannot be performed.

However, when such a color liquid crystal display device is used as a display device of a mobile phone, for example, and the liquid crystal display device is in a waiting mode or is used for a long time outdoors, there exists a strong demand for the realization of color display using the ambient light (the white light) such as the sun beams.

As a display device which can satisfy such a demand, there has been known a display device which performs a color display using a white ambient light by providing color filters on an outer portion of a liquid crystal display panel (a liquid crystal cell) and by mechanically moving the color filters with respect to respective pixels (see patent literature 1).

[patent literature 1]

Japanese Unexamined Patent Publication 2002-328355

However, such a liquid crystal display device has a drawback that the liquid crystal display device includes the mechanical operation of color filters and hence, the liquid crystal display device exhibits the poor reliability in operation. The liquid crystal display device also has a drawback that the liquid crystal display device includes a mechanical device for moving the color filters and hence, there exists a limit with respect to the miniaturization of a device per se.

The present invention has been made under such circumstances and it is an object of the present invention to provide a liquid crystal display device which can exhibit the high reliability and can realize the miniaturization by eliminating a mechanical operating mechanism.

SUMMARY OF THE INVENTION

To briefly explain the summary of representative inventions among inventions disclosed in this specification, they are as follows.

Means 1.

In a liquid crystal display device according to the present invention, for example, at least a light guide plate which guides lights from a light source, a liquid crystal display panel, an optical medium which changes over transmission and reflection of lights, color filters and a reflector are sequentially arranged from a viewer side,

the lights from the light source sequentially change over respective colors thereof which constitute three primary colors, pass through the liquid crystal display panel and, thereafter, are reflected toward the viewer side by the optical medium, and at the same time,

the color filters are constituted of color filters of respective colors which are arranged to face at least three pixels formed on the liquid crystal display panel which are disposed

close to each other and the respective colors constitute the three primary colors, and

the reflector reflects an ambient light which is made to pass through the light guide plate, the liquid crystal display panel, the optical medium and the color filters to the viewer side.

Means 2.

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of means 1, characterized in that the color filters are formed on a surface of the reflector.

Means 3.

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of means 1, characterized in that the liquid crystal display device includes a display control circuit and an ON/OFF state of the light source is determined by the display control circuit, wherein when the light source is in the ON state, video signals of the colors corresponding to lights of respective colors from the light source are supplied to respective pixels in response to the changeover of lights of respective colors, and when the light source is in the OFF state, video signals of colors corresponding to the colors of the color filters which are arranged to face at least three respective pixels disposed close to each other are supplied to the respective pixels.

Means 4.

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of means 3, characterized in that when the light source is in the ON state, among at least three pixels which are disposed close to each other, the video signals which are supplied to the pixels other than the selected pixels which are small in number than the three pixels are removed for thinning.

Means 5.

In a liquid crystal display device according to the present invention, for example, at least a liquid crystal display panel which uses transparent substrates which are arranged to face each other with liquid crystal therebetween as an envelope and a light guide plate which guides light from a light source are sequentially arranged from a viewer side,

the liquid crystal display panel forms light reflection layers on a liquid-crystal-side surface of the light-guide-plate side transparent substrate using portions of respective pixels and forms color filters which face the light reflection layers on the liquid-crystal-side surface of the transparent substrate or a liquid-crystal-side surface of another transparent substrate which faces the transparent substrate, and

light from the light source is irradiated such that respective colors which constitute three primary colors are sequentially changed over.

Means 6.

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of means 5, characterized in that an area of the reflection layers is set at a rate of equal to or less than 1/3 of an area of regions of the pixels.

Means 7.

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of means 5, characterized in that each pixel is constituted of a thin film transistor which is turned on in response to the supply of a scanning signal from the gate signal line and a pixel electrode to which a video signal is supplied from a drain signal line through the thin film transistor, wherein the reflection layer is constituted of an extension portion of the gate signal line or the drain signal line.

Means 8.

In a liquid crystal display device according to the present invention, for example, at least a light guide plate which guides lights from a light source, a liquid crystal display panel, an optical medium which changes over transmission and reflection of lights, color filters of respective colors which constitute three primary colors and a reflector are sequentially arranged from a viewer side,

the light source irradiates lights such that the irradiated

lights are sequentially changed over with respective colors which constitute three primary colors,

the liquid crystal display panel is divided into three pixel regions which face the respective colors of the color filters in each pixel, and

the liquid crystal display device includes means which simultaneously supplies the video signal to the respective pixel regions and means which independently supplies a black display signal to the respective pixel regions.

Means 9.

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of means 8, characterized in that the video signal is supplied to respective pixel regions through video signal lines and the black display signal is supplied to the pixel regions through the video signal lines.

Means 10.

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of means 8, characterized in that when the light is irradiated from the light source, the black display signal is not supplied to the respective pixel regions and, when the light is not irradiated from the light source, the video signal is supplied to the respective pixel regions and, thereafter, the black display signal is supplied to the remaining pixel regions other

than the pixel regions which correspond to the color which is allocated to the video signal.

Means 11.

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of means 8, characterized in that the video signals are supplied to the respective pixel regions through video signal lines and the black display signal is supplied to the respective pixel regions through signal lines which are provided separately from the video signal lines.

Means 12.

In a liquid crystal display device according to the present invention, for example, at least a light guide plate which guides lights from a light source, a liquid crystal display panel, an optical medium which changes over transmission and reflection of lights, color filters of respective colors which constitute three primary colors and a reflector are sequentially arranged from a viewer side,

the light source irradiates lights such that the irradiated lights are sequentially changed over among respective colors which constitute three primary colors,

the liquid crystal display panel is divided into three pixel regions which face the respective colors of the color filters in each pixel, and

the video signal from the same drain signal line is

configured to be supplied to respective pixel electrodes of the respective pixel regions through a first thin film transistor which is driven in response to the supply of the scanning signal from the first gate signal line, through a second thin film transistor which is driven in response to the supply of the scanning signal from the second gate signal line, and through a third thin film transistor which is driven in response to the supply of the scanning signal from the third gate signal line.

Means 13.

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of means 12, characterized in that the video signal includes a black display signal, the respective displays of the respective pixel regions are sequentially performed by changing over the respective displays of the respective pixel regions, and a black display based on the black display signal is performed at the time of changing over the display.

Here, the present invention is not limited to the above-mentioned constitution and various modifications are conceivable without departing from the technical concept of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a constitutional view showing one embodiment of a liquid crystal display device according to the present

invention;

Fig. 2 is a view showing optical paths during an operation in a reflection mode and in a transmission mode of the liquid crystal display device shown in Fig. 1;

Fig. 3 is a constitutional view showing one embodiment of the relationship between a pixel and a colored reflector in the liquid crystal display device shown in Fig. 1;

Fig. 4 is an explanatory view showing one embodiment of manner of displaying in the reflection mode and in the transmission mode of the liquid crystal display device shown in Fig. 1;

Fig. 5 is a constitutional view showing another embodiment of the relationship between the pixel and the colored reflector in the liquid crystal display device shown in Fig. 1;

Fig. 6 is a constitutional view showing another embodiment of the liquid crystal display device according to the present invention;

Fig. 7 is a constitutional view showing another embodiment of the liquid crystal display device according to the present invention;

Fig. 8 is a constitutional view showing another embodiment of the liquid crystal display device according to the present invention;

Fig. 9 is a constitutional view showing another embodiment of the liquid crystal display device according to the present

invention;

Fig. 10 is a time chart showing an embodiment of a driving method of the liquid crystal display device shown in Fig. 9;

Fig. 11 is a constitutional view showing another embodiment of the liquid crystal display device according to the present invention and also is a timing chart showing an embodiment of a driving method thereof;

Fig. 12 is a constitutional view showing another embodiment of the liquid crystal display device according to the present invention and also is a timing chart showing an embodiment of a driving method thereof; and

Fig. 13 is an explanatory view showing an embodiment of an equipment in which the liquid crystal display device according to the present invention is incorporated.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of a liquid crystal display device according to the present invention are explained in conjunction with drawings hereinafter.

Embodiment 1.

First of all, Fig. 1 is an explanatory view showing one embodiment of the liquid crystal display device according to the present invention, wherein Fig. 1(a) is a plan view and Fig. 1 (b) is a cross-sectional view taken along a line b-b and also is a view showing a circuit for supplying signals to parts of

the liquid crystal display device shown in Fig. 1(a).

In Fig. 1(b), there is shown a liquid crystal display panel PNL. The liquid crystal display panel PNL is configured such that an envelope is formed of transparent substrates which are arranged to face each other with liquid crystal therebetween and the display panel PNL includes a large number of pixels which are arranged in a matrix array in the spreading direction of the liquid crystal.

The liquid crystal display panel PNL is, for example, an active-matrix-type liquid crystal display panel and is constituted as a so-called transmissive type. Here, the transmissive type means a liquid crystal display panel in which no reflector is provided and is constituted of pixels which can transmit light from one surface of the liquid crystal display panel PNL to another surface thereof. Further, the liquid crystal display panel PNL includes no color filters in the inside thereof.

Here, the liquid crystal display panel PNL is configured to perform a display upon receiving signals from a driving circuit DRV1 which is driven by a display control circuit TCON.

On a viewer-side surface of the liquid crystal display panel PNL, a light guide plate GLB is arranged by way of a polarization plate POL. The polarization plate POL and the light guide plate GLB are arranged such that both of the polarization plate POL and the light guide plate GLB can cover at least a

liquid crystal display part.

On a side wall surface of the light guide plate GLB, as shown in Fig. 1(a), for example, a red light emitting diode RD, a green light emitting diode GD and a blue light emitting diode BD are arranged. These respective diodes are made to emit light using a lighting control device LCA. The lights emitted from the respective diodes RD, GD, BD enter the inside of the light guide plate GLB through a side wall surface thereof and is irradiated to the liquid crystal display device panel PNL side.

The respective diodes RD, GD, BD are configured to emit lights in response to signals supplied from the lighting control device LCA which is driven by the display control circuit TCON. In this case, as shown in Fig. 1(c), along with the lapse of time, the emission of lights and the extinction of lights are repeated in order of the red light emitting diode RD, the green light emitting diode GD and the blue light emitting diode BD, for example. In Fig. 1(c), time t is taken on an axis of abscissas and brightness B is taken on an axis of ordinates.

On a back surface of the liquid crystal display panel PNL, an optical medium LM is arranged such that the optical medium LM covers at least the liquid crystal display part of the liquid crystal display panel PNL. The optical medium LM is constituted to have a function of a reflector and a function of a light transmitting plate by switching. That is, the optical medium LM has a function of a light transmitting plate when used in

a light transmitting mode (when the light source LT is turned off) and has a function of a reflector when used in a light reflecting mode (when the light source LT is turned on).

The switching of the respective functions of the optical medium LM is performed in response to signals supplied from a driving circuit DRV2 which is driven by the display control circuit TCON.

On a back surface of the optical medium LM, a colored reflector CRF is arranged such that the colored reflector CRF covers at least the liquid crystal display part of the liquid crystal display panel PNL. The colored reflector CRF is provided with color filters on a surface thereof which faces the optical medium LM, for example. Colors of the color filters are constituted of red, green and blue respectively and the color filters are formed corresponding to the respective pixels of the liquid crystal display panel PNL.

Fig. 2 is an explanatory view showing the manner of operation of the above-mentioned liquid crystal display device, wherein Fig. 2(a) indicates a case in which the liquid crystal display device is used in the reflection mode and Fig. 2(b) indicates a case in which the liquid crystal display device is used in the transmission mode.

First of all, in the reflection mode shown in Fig. 2(a), with respect to the respective pixels of the liquid crystal display panel PNL, the optical transmissivity is controlled in

response to the image data, lights are supplied from the respective diodes RD, GD, BD, and the optical medium LM is set to have the light reflecting function.

That is, the lights emitted from the red diode RD, the green diode GD and the blue diode BD are sequentially incident on the liquid crystal display panel PNL in a repeated manner through the light guide plate GLB, and these lights are incident on the optical medium LM through the liquid crystal in the inside of the liquid crystal display panel PNL. Here, at the timing of the incidence of the lights from the respective diodes, the image data for red, green and blue are inputted to the liquid crystal display panel PNL and the respective pixels are driven corresponding to the image data.

The lights incident on the optical medium LM are reflected on the optical medium LM and are made to be irradiated to the viewer side through the liquid crystal in the liquid crystal display panel PNL again and, further, through the light guide plate GLB.

The viewer receives, with respect to the respective pixels, the red, green and blue lights which have passed through the liquid crystal thereof. Since the lights at this point of time respectively include the pixel information for red, green and blue, the viewer can perceive the pixels having the mixed color of red, green and blue.

Further, in the transmission mode shown in Fig. 2(b), the

respective pixels of the liquid crystal display panel PNL are formed such that the optical transmissivity of the liquid crystal is controlled in response to the image data, the supply of lights from the respective diodes RD, GD, BD is turned off, and the optical medium LM has the light transmitting function.

That is, on the liquid crystal display panel PNL, an ambient light such as sun beams or the like, for example, is incident through the light guide plate GLB and, thereafter, the light is incident on the optical medium LM through the liquid crystal in the liquid crystal display panel PNL. In this case, image data for red, green and blue are inputted to the respective neighboring three pixels in the liquid crystal display panel PNL and the above-mentioned ambient light is made to pass through the liquid crystal of these respective pixels.

The light incident on the above-mentioned optical medium LM is made to pass through the optical medium LM and is reflected on the colored reflector CRF. In this case, on the colored reflector CRF, the red filters, the green filters and the blue filters are formed respectively such that these filters face the pixels to which image data for red, green and blue are inputted in the liquid crystal display panel PNL.

Then, the light reflected on the colored reflector CRF is made to be irradiated to the viewer side through the optical medium LM, the liquid crystal display panel PNL and the light guide plate GLB.

The viewer receives the red, green and blue lights with respect to the neighboring three pixels. At this point of time, since the lights include the respective pixel information for red, green and blue, the viewer can perceive the pixels of the mixed color consisting of red, green and blue.

As clearly understood from the above-mentioned explanation, the liquid crystal display panel PNL is constituted such that, when the liquid crystal display panel PNL is used in the reflection mode, the unit pixel for color display is constituted of one pixel and, when the liquid crystal display panel PNL is used in the transmission mode, the unit pixel for color display is constituted of at least three pixels.

Fig. 3 is a view showing a relationship between the pixel of the liquid crystal display panel PNL and the color filters CF of the colored reflector CRF.

First of all, Fig. 3(a) is a cross-sectional view showing a portion of one pixel of the liquid crystal display panel PNL, the optical medium LM and the colored reflector CRF which are sequentially arranged on the back surface of the liquid crystal display panel PNL.

In the liquid crystal display panel PNL, the transparent substrates SUB1, SUB2 which are arranged to face each other with the liquid crystal LQ therebetween form the envelope, strip-shaped transparent counter electrodes CT which extend in the x direction in the drawing and are arranged in parallel in

the z direction are formed on the liquid-crystal-side surface of the transparent substrate SUB2, and strip-shaped transparent pixel electrodes PX which extend in the z direction in the drawing and are arranged in parallel in the x direction are formed on the liquid-crystal-side surface of the transparent substrate SUB1.

A crossing portion where the pixel electrode PX and the counter electrode CT are superposed on each other constitutes one pixel and the optical transmissivity of the liquid crystal of the portion can be controlled by the electric field which is generated at the crossing portion.

Here, it is needless to say that, the constitution of the pixel of the liquid crystal display panel PNL is not limited to such a constitution and can adopt other constitution.

Further, in this embodiment, the optical medium LM is constituted such that electrodes TM1, TM2 are formed on respective front and back surfaces of a material layer PDLC and, by applying a voltage to these electrodes TM1, TM2, the optical medium LM per se functions as the reflector or the light transmitting plate.

When the liquid crystal display panel PNL is viewed from the y direction side in the drawing, the respective pixels PIX are arranged in a matrix array, as shown in Fig. 3(b).

Here, when the liquid crystal display panel PNL is used in the reflection mode (the light source LT being turned on),

as shown in Fig. 3(c), the unit pixel for color display (a portion surrounded by a dotted line) is constituted of each pixel PIX. This is because that the lights emitted from the above-mentioned diodes RD, GD, BD repeatedly and sequentially pass through each pixel PIX.

Further, when the liquid crystal display panel PNL is used in the transmission mode (light source LT being turned off), as shown in Fig. 3(d), the unit pixel for color display is constituted of, for example, nine pieces of pixels PIX which are arranged close to each other (a portion being surrounded by a dotted line).

These nine pieces of pixels PIX take the 3×3 matrix arrangement and, out of these nine pieces of pixels PIX, three pieces of respective pixels PIX which are arranged in parallel in the z direction in the drawing at the left side in the drawing are allocated to red, three pieces of respective pixels PIX which are arranged in parallel in the z direction in the drawing at the center side in the drawing are allocated to green, and further, three pieces of respective pixels PIX which are arranged in parallel in the z direction in the drawing at the right side in the drawing are allocated to blue.

In this case, the pixel PIX which is allocated to red means the pixel PIX through which the red light passes and, on the surface of the colored reflector CRF which faces the portion, as shown in Fig. 3(e), the red filter FIL is formed. Similarly,

the green filter FIL is formed on the surface of the colored reflector CRF which faces the pixel PIX which is allocated to green and the blue filter FIL is formed on the surface of the colored reflector CRF which faces the pixel PIX which is allocated to blue.

In such a constitution, when the light source is turned on (the reflection mode), the unit pixel for color display is constituted of one pixel and, when the light source is turned off (the transmission mode), the unit pixel for color display is constituted of a plurality of pixels (more than three pixels) and hence, the color display can be realized using the ambient light. In this case, the ON/OFF of the light source LT is controlled by the display control circuit TCON and hence, the ON/OFF of the light source LT can be easily judged by the display control circuit TCON.

In Fig. 4, as explained above, the number of pixels which constitute the unit pixel for color display is different depending on whether the light source LT is in the ON state or in the OFF state and hence, the number of data at the light source ON time may be thinned using the number of the data at the light source OFF time as the reference.

Fig. 4(a) is a view which shows a portion of the display mode at the light source ON time and indicates supplying of data to the center pixel (A1, A2, A3, A4) out of the 3×3 pixels which are arranged close to each other. That is, the thinning of the

data is performed such that the original information can be displayed even when the resolution is decreased. Here, it is needless to say that, besides the simple thinning, it is also possible to perform an interpolating calculation for smoothing the data connection.

Fig. 4(b) is a view which shows a portion of the display mode at the light source OFF time and corresponds to Fig. 4(a). In the 3×3 pixels which are arranged close to each other as the unit pixel for color display, the respective pixels which constitute the same color are displayed by the same data thus enabling the display of a dedicated screen (a waiting screen).

With such a constitution, the resolution of the display changes between when the light source LT is in the ON state and the light source LT is in the OFF state and hence, for reducing the difference in display qualities between these states, it is desirable that the resolution of the original pixel is set high. In this case, it is desirable that, as a pixel size, one pixel is equal to or less than 150μm, particularly, equal to or less than 100μm. This is because that, since the original pixel size is small, even at the light source OFF time, it is possible to prevent the excessive increase of the size of the unit pixel for color display light and hence, it is possible to prevent the viewer from having an impression that the resolution is degraded. Further, this is because that, when the sized of one pixel is set equal to or less than 100μm, the

display region size at an enlarged display becomes a size equivalent to so-called 15″XGA and hence, it is possible to prevent the viewer from having an impression that the resolution is degraded. In view of the above, the resolution of equal to or more than 1/4VGA, possibly equal to or more than VGA is desirable.

Here, with respect to the case shown in Fig. 4(b), in the unit pixel for color display which is constituted of 3×3 pieces of pixels, three pixels at the right side are allocated to red, three pixels at the center are allocated to green and three pixels at the left side are allocated to blue. However, it is needless to say that these arrangements may be changed. For example, as shown in Fig. 5(a), with respect to the three pixels arranged at the right side, these pixels are respectively allocated to red, blue and green from above. With respect to the three pixels at the center, these pixels are respectively allocated to green, red and blue from above. Further, with respect to three pixels at the left side, these pixels are respectively allocated to blue, green and red from above. In this case, as shown in Fig. 4(b), the respective color filters FIL which are formed on the colored reflector CRF are formed at corresponding portions of the color reflector CRF which face the above-mentioned respective colors to which the respective color filters FIL are allocated. Further, in Fig. 4(a), one pixel is displayed using 3×3 pixels. However, it may be possible to adopt a thinning method in which one pixel is displayed using three RGB pixels which are arranged

horizontally in a row.

With such a constitution, the ratio of arrangement of red, green and blue in the unit pixel for color display becomes uniform and hence, the separation of red, green and blue is hardly recognized with naked eyes. Accordingly, it appears that lights are irradiated from the whole unit pixel whereby the display quality is improved. Here, although the rearrangement of data is necessary in this case, this rearrangement can be easily performed by the display control circuit TCON.

Further, in the liquid crystal display device shown in Fig. 1, the light guide plate GLB is arranged closer to the viewer side than to the liquid crystal display panel PNL. However, as shown in Fig. 6, it is needless to say that the light guide plate GLB may be arranged on the back surface of the liquid crystal display panel PNL and in front of the optical medium LM. This is because that the constitution can obtain the similar advantageous effects.

However, in the liquid crystal display device shown in Fig. 1, even when a thickness of the light guide plate GLB becomes comparatively large, blurring of the reflected light is hardly generated and hence, it is possible to obtain an advantageous effect that the liquid crystal display device can sufficiently cope with the high resolution.

Embodiment 2.

Fig. 7(a) is a cross-sectional view showing another

embodiment of the liquid crystal display device according to the present invention. Compared with the liquid crystal display device shown in Fig. 6, for example, the liquid crystal display device of this embodiment is provided with neither the optical medium LM nor the colored reflector CRF. This is because that the respective functions brought about by the optical medium LM and the colored reflector CRF are provided in the inside of the liquid crystal display panel PNL.

Fig. 7(b) is a view showing a cross section of a portion of one pixel of the liquid crystal display panel PNL. Here, the light guide plate GLB is arranged on the back surface of the liquid crystal display panel PNL when viewed from the viewer side.

The constitution of the liquid crystal display panel PNL is substantially equal to the constitution of the liquid crystal display panel shown in Fig. 3(a). However, the difference lies in that the liquid crystal display panel PNL is provided with color filters CF and reflection layers RF.

First of all, the color filters CF are formed on portions of the pixels formed on the liquid-crystal-side surface of the transparent substrate SUB2, for example. In the case shown in Fig. 7(b), the color filters CF are formed on the liquid-crystal-side surface of the transparent substrate SUB2 and a counter electrode CT is formed such that the counter electrode CT also covers the color filters CF.

Further, reflection layers RF are formed on portions of the pixels formed on the liquid-crystal-side surface of the transparent substrate SUB1 and are formed in the substantially same pattern at the position facing the above-mentioned color filters CF. With respect to the case of Fig. 7(b), the reflection layers RF are formed on the liquid-crystal-side surface of the transparent substrate SUB1 and the pixel electrodes PX are formed on the upper surface of the insulation film which is formed such that the insulation film also covers the reflection layers RF.

In the liquid crystal display device constituted in such a manner, as shown in Fig. 7(c), when the light source LT is turned on, the lights from the light source LT which pass through the transparent substrate SUB1 reach the viewer side through the liquid crystal LQ in a region of the pixel where the above-mentioned reflection layers RF are not formed and through the transparent substrate SUB2.

The lights having respective colors of red, green and blue are sequentially changed over and are irradiated from the above-mentioned light source LT and hence, even when the lights do not pass through the color filters CF which are formed on the transparent substrate SUB2 side, the viewer can recognize the mixed color.

Further, as shown in Fig. 7(d), when the light source LT is turned off, with respect to an ambient light such as sun beams

or the like, the light which passes through the transparent substrate SUB2, the liquid crystal LQ and is reflected on the above-mentioned reflection layers RF passes through the color filters CF which are formed on the transparent substrate SUB2 side and reaches to the viewer. In this case, other lights which are not reflected on the above-mentioned reflection layer RF are made to pass through the liquid crystal display panel PNL and the light guide plate GLB and hence, other lights do not reach the viewer.

Here, in the above-mentioned constitution, it is desirable that the regions of the color filters CF have an area approximately 1/2 to twice as large as an area of the reflection layers RF. Due to such a constitution, it is possible to satisfy both of the suppression of coloring at the light transmission time and the high color purity at the light reflection time.

In this case, an area ratio of the reflection layers RF with respect to the pixel electrodes PX can be suitably selected according to an object of use, that is, according to whether the transmission manner is mainly performed or the reflection manner is mainly performed. In this case, for suppressing the influence of the reflection light during light transmitting, it is desirable that the area ratio of the reflection layers RF is set equal to or less than 1/3 with respect to the area of the pixel electrode PX. Due to such a constitution, it is possible to prevent the excessive influence of the color of the

reflection light with respect to three respective colors of red, green and blue.

In this manner, in case the color filters CF of one color are formed in each pixel, when the light source LT is turned on, the display of three colors can be obtained with one pixel. On the other hand, when the light source LT is turned off, the display of one color can be obtained with one pixel.

Accordingly, as shown in the embodiment 1, by allocating the color filters having three primary colors to at least three pieces of pixels which are arranged close to each other, the unit pixel for color display can be constituted when the light source is turned off.

Further, the color filters CF may be positioned on the same substrate as the light reflection layers RF provided that the color filters CF are arranged in conjunction with the light reflection layers RF in a plan view.

Fig. 8(a) is a plan view of one pixel when the constitution shown in Fig. 7(b) is viewed from the liquid crystal side. The pixel PIX is formed such that the pixel PIX is surrounded by the gate signal lines GL which extend in the x direction in the drawing and are arranged in parallel in the y direction and the drain signal lines DL which extend in the y direction in the drawing and are arranged in parallel in the x direction. With respect to the pixel PIX, a semiconductor layer SC is formed on a portion of the gate signal line GL (a lower side in the

drawing) by way of an insulation film not shown in the drawing such that the semiconductor layer SC traverses the gate signal line GL thus forming a thin film transistor TFT in which the semiconductor layer SC becomes conductive from one end thereof to another other end thereof by supplying the scanning signals to the gate signal lines GL.

One end of the semiconductor layer SC is electrically connected to one drain signal line DL (left side in the drawing) with respect to the pixel PIX and another end of the semiconductor layer SC is electrically connected to the pixel electrode PX.

The pixel electrode PX is formed in a most portion at the center of the pixel PIX except for peripheries of the pixel PIX and the distance between the pixel PX and the drain signal line DL is set comparably larger than the distance between the pixel PX and the gate signal line GL so as to control the peripheries thereof.

In the region between the pixel electrode PX and the drain signal line DL, the reflection film RF is formed and a side of the reflection film RF at the pixel electrode PX side is formed such that the side of the reflection film RF is superposed on the pixel electrode PX. As mentioned above, the area of the reflection films RF is substantially defined by the area of the color filters CF at the transparent substrate SUB2 side.

Further, Fig. 8(b) is a plan view showing another embodiment of the pixel of the liquid crystal display device

according to the present invention and corresponds to Fig. 8(a). Further, Fig. 8(c) is a cross-sectional view taken along a line c-c in Fig. 8(b).

The constitution which makes the embodiment shown in Fig. 8(b) different from the constitution of the embodiment shown in Fig. 8(a) lies in that the reflection film RF which is arranged close to the drain signal line DL is physically connected with, that is, is integrally formed with the reflection film RF of other pixel PIX which is arranged close to the pixel PIX. Accordingly, the reflection film RF having such a constitution is formed in a state that the reflection film RF has a portion thereof superposed on the drain signal line DL.

By constituting the liquid crystal display device in such a manner, in the vicinity of both sides of the drain signal line DL, a light shielding function can be obtained. Accordingly, leaking of the light at the portion can be prevented.

Further, Fig. 8(d) is a plan view showing another embodiment of the pixel of the liquid crystal display device according to the present invention and corresponds to Fig. 8(a).

The constitution which makes the embodiment shown in Fig. 8(d) different from the embodiment shown in Fig. 8(a) lies in that the above-mentioned reflection film RF is positioned on the same layer as the gate signal line GL and, at the same time, one end of the reflection film RF is physically and electrically connected with the gate signal line GL.

In this embodiment, for example, the reflection film RF is connected with other gate signal line GL (the gate signal line in the upper side in the drawing) which surrounds the pixel together with the gate signal line GL which drives the pixel. In such a constitution, a side of the reflection film RF at the pixel electrode PX side is superposed on the pixel electrode PX by way of an insulation film not shown in the drawing and, a capacitive element Cadd can be formed between the pixel electrode PX and the above-mentioned gate signal line GL at the portion.

Here, when the capacitive signal line is formed in the x direction in the drawing within the pixel PIX for forming the capacitive element Cadd, it is needless to say that the capacitive signal line and the reflection film RF may be integrally formed.

Further, Fig. 8(e) is a plan view showing another embodiment of the pixel of the liquid crystal display device according to the present invention and corresponds to Fig. 8(b).

In this case also, the above-mentioned reflection film RF is positioned on the same layer as the gate signal line GL and, at the same time, one end of the reflection film RF is physically and electrically connected to the gate signal line GL.

Further, the reflection film RF is formed such that the reflection film RF has a portion thereof superposed on the drain signal line DL thus providing a light shielding function in the

vicinity of both sides of the drain signal line DL.

Further, Fig. 8(f) is a plan view showing another embodiment of the pixel of the liquid crystal display device according to the present invention and corresponds to Fig. 8(b).

In the embodiment shown in Fig. 8(b), the reflection film RF and the drain signal line DL are formed on the different layers. In the embodiment shown in Fig. 8(f), the reflection film RF and the drain signal line DL are formed on the same layer and also integrally.

Due to such a constitution, the drain signal line DL can be configured to function also as the reflection film RF and, further, the electric resistance of the drain signal line DL per se can be decreased.

Further, Fig. 8(g) is a plan view showing another embodiment of the pixel of the liquid crystal display device according to the present invention and corresponds to Fig. 8(c).

In the embodiment shown in Fig. 8(c), the pixel electrode PX and the reflection film RF are formed on the different layers by way of the insulation film. However, in the embodiment shown in Fig. 8(g), the pixel electrode PX and the reflection film RF are formed of different materials and, at the same time, the pixel electrode PX and the reflection film RF are formed in a superposed manner without interposing any insulation film therebetween.

Due to such a constitution, by selecting a material having

the small electric resistance as the material of the reflection film RF, the electric resistance of the pixel electrode PX per se can be decreased.

Embodiment 3.

Fig. 9(a) is a plan view showing another embodiment of the pixel of the liquid crystal display panel according to the present invention.

One pixel of the liquid crystal display panel PNL is positioned between gate signal lines GL which extend in the x direction in the drawing and are arranged in parallel in the y direction in the drawing as well as between drain signal lines DL which extend in the y direction in the drawing and are arranged in parallel in the x direction in the drawing.

Due to such a constitution, in a pixel region which is surrounded by the respective signal lines, for example, three pixel electrodes PX1, PX2, PX3 which are arranged in the x direction are formed.

The respective pixel electrode PX1, PX2, PX3 are electrically connected with respective one ends of semiconductor layers SC1, SC2, SC3 which are arranged such that the semiconductor layers SC1, SC2, SC3 traverse the gate signal line GL which is arranged at an upper side in the drawing and an insulation film not shown in the drawing and, another ends of the semiconductor layers SC1, SC2, SC3 are connected in common and are electrically connected to the drain signal line DL which

is arranged at the left side of the drawing, for example. The semiconductor layers SC1, SC2, SC3 are respective semiconductor layers of thin film transistors TFT1, TFT2, TFT3, wherein when a scanning signal is supplied to the gate signal lines GL which are arranged to cross the thin film transistors TFT1, TFT2, TFT3, a video signal from the drain signal line DL is supplied to respective pixel electrodes PX1, PX2, PX3.

Further, in a region defined between the respective pixel electrodes PX1, PX2, PX3 and the gate signal line GL which is arranged at the lower side in the drawing, three auxiliary scanning signal lines RL1, RL2, RL3 extend in the x direction in the drawing and are arranged in parallel in the y direction.

Then, the pixel electrode PX1 is electrically connected with the auxiliary scanning signal line RL1 and one end of the semiconductor layer SC4 which is arranged such that the semiconductor layer SC4 traverses an insulation film not shown in the drawing, while another end of the semiconductor layer SC4 is electrically connected with the drain signal line DL which is arranged at the left side in the drawing. The semiconductor layer SC4 is a semiconductor layer of a thin film transistor TFT4, wherein when a signal is supplied to the auxiliary scanning signal line RL1 which is arranged to cross the thin film transistor TFT4, a signal from the drain signal line DL (a black display signal described later) is supplied to the pixel electrode PX1.

In the same manner, the pixel electrode PX2 is electrically

connected with the auxiliary scanning signal line RL2 and one end of the semiconductor layer SC5 which is arranged such that the semiconductor layer SC5 traverses an insulation film not shown in the drawing, while another end of the semiconductor layer SC5 is electrically connected with the drain signal line DL which is arranged at the left side in the drawing. The semiconductor layer SC5 is a semiconductor layer of a thin film transistor TFT5, wherein when a signal is supplied to the auxiliary scanning signal line RL2 which is arranged to cross the thin film transistor TFT5, a signal from the drain signal line DL (a black display signal described later) is supplied to the pixel electrode PX2.

In the same manner, the pixel electrode PX3 is electrically connected with the auxiliary scanning signal line RL3 and one end of the semiconductor layer SC6 which is arranged such that the semiconductor layer SC6 traverses an insulation film not shown in the drawing, while another end of the semiconductor layer SC6 is electrically connected with the drain signal line DL which is arranged at the left side in the drawing. The semiconductor layers SC6 is a semiconductor layer of a thin film transistor TFT6, wherein when a signal is supplied to the auxiliary scanning signal line RL3 which is arranged to cross the thin film transistors TFT6, a signal from the drain signal line DL (a black display signal described later) is supplied to the pixel electrode PX3.

The liquid crystal display panel PNL having such a constitution includes, as shown in Fig. 9(b), with respect to the pixel PIX, the pixel electrodes PX1, PX2, PX3 which are allocated to respective colors, and a red color filter FIL, a green color filter FIL and a blue color filter FIL are formed on a colored reflector CRF such that the these color filters FIL face the pixel electrodes PX1, PX2, PX3.

Further, the liquid crystal display device is constituted such that, as shown in Fig. 9(c), a light guide plate GLB is arranged on a viewer-side surface of the liquid crystal display panel PNL and an optical medium LM and the colored reflector CRF are sequentially arranged on a back surface of the liquid crystal display panel PNL.

According to the liquid crystal display device having such a constitution, when a light source LT is turned on, the auxiliary scanning signal line RL1, the auxiliary scanning signal line RL2 and the auxiliary scanning signal line RL3 are always turned off and hence, a video signal is supplied to the respective pixel electrodes PX1, PX2, PX3 from the drain signal line DL through the thin film transistors TFT1, TFT2, TFT3 which are driven in response to the supply of a scanning signal from the gate signal line GL.

Here, as the video signal used in such an operation, a gray scale signal for red, a gray scale signal for green and a gray scale signal for blue are sequentially supplied and

respective red, green and blue lights from the light guide plate GLB are irradiated in a sequentially-changed-over manner. Further, the lights from the light guide plate GLB are made to pass through or to be reflected on the pixel electrodes PX1, PX2, PX3 and hence, the respective lights from the pixel can be recognized in a mixed state by a viewer.

Further, when the light source is turned off, at the timing of sequentially displaying the pixel in order of red → green → blue, first of all, to perform the red display, data is written in the pixel electrodes PX1, PX2, PX3 through the gate signal line GL and, thereafter, black data is supplied to the drain signal line DL and the auxiliary scanning signal lines RL2 and the auxiliary scanning signal lines RL3 are turned on so as to make the pixel electrode PX2, PX3 portions perform a black display. Accordingly, the pixel electrode PX1 portion performs a red display.

Next, to perform the green display, data is written in the pixel electrodes PX1, PX2, PX3 through the gate signal line GL and, thereafter, black data is supplied to the drain signal line DL and the auxiliary scanning signal lines RL1 and the auxiliary scanning signal lines RL3 are turned on so as to make portions of the pixel electrode PX1, PX3 perform a black display. Accordingly, the pixel electrode PX2 portion performs a green display.

Next, to perform the blue display, data is written in the

pixel electrodes PX1, PX2, PX3 through the gate signal line GL and, thereafter, black data is supplied to the drain signal line DL and the auxiliary scanning signal lines RL1 and the auxiliary scanning signal lines RL2 are turned on so as to make portions of the pixel electrodes PX1, PX2 perform a black display. Accordingly, the pixel electrode PX2 portion performs a blue display.

Due to such an operation, it is possible to allow the viewer to recognize the reflection display of respective colors without lowering the resolution of the display.

Fig. 10(a) is a timing chart showing, in the above-mentioned liquid crystal display device, respective displays of the pixel electrode PX1, the pixel electrode PX2 and the pixel electrode PX3 when the video signal is supplied to the drain signal line DL, when the scanning signal is supplied to the gate signal line GL, and when the respective signals are supplied to the auxiliary scanning signal line RL1, the auxiliary scanning signal line RL2 and the auxiliary scanning signal line RL3. The timings for supplying respective signals in the timing chart are as described above.

In the timing chart, TR indicates an R display period, TG indicates a G display period and TB indicates a B display period. Further, PR indicates only an R region, PG indicates only an G region and PB indicates only an B region.

Further, Fig. 10(b) shows a case in which the supply of

signals different from supply of signals in Fig. 10(a) is performed. Compared to the supply of signals shown in Fig. 10(a), rises of respective signals supplied to the auxiliary scanning signal lines RL1, the auxiliary scanning signal lines RL2 and the auxiliary scanning signal lines RL3 are overlapped to the scanning signal supplied to the gate signal line GL and, at the same time, falls of the respective signals which are supplied to the auxiliary scanning signal lines RL1, the auxiliary scanning signal lines RL2 and the auxiliary scanning signal lines RL3 are made to come after the fall of the scanning signal which is supplied to the gate signal line GL.

Due to such a constitution, it is possible to make the regions of colors other than the color to be displayed perform a black display in a shorter period and hence, the further enhancement of the color purity is obtained.

Embodiment 4.

Fig. 11(a) is a plan view showing another embodiment of the pixel of the above-mentioned liquid crystal display panel PNL and corresponds to Fig. 9(a).

The constitution which makes this embodiment different from the embodiment shown in Fig. 9(a) lies in that, for example, an auxiliary video signal line RD which is used as a dedicated line for black writing is provided close to the drain signal line DL which supplies the video signal to the drain signal line DL and a black signal is supplied to the respective pixel

electrodes PX1, PX2, PX3 from the auxiliary video signal line RD through the thin film transistor TFT4 which is turned on by the auxiliary scanning signal line RL1, the thin film transistor TFT5 which is turned on by the auxiliary scanning signal line RL2 and the thin film transistor TFT6 which is turned on by the auxiliary scanning signal line RL3.

Due to such a constitution, it is possible to constitute the liquid crystal display device without changing the signal writing of a conventional so-called field sequential method. A potential for black display can be always supplied to the auxiliary video signal line RD. For example, in a normally black mode, a potential which is supplied to the counter electrode CT, that is, a so-called common potential may be supplied to the auxiliary video signal line RD.

Fig. 11(b) is a timing chart showing, in the liquid crystal display panel PNL having the above-mentioned pixels, respective displays of the pixel electrode PX1, the pixel electrode PX2 and the pixel electrode PX3 when the video signal is supplied to the drain signal line DL, when the scanning signal is supplied to the gate signal line GL, when the signal is supplied to the auxiliary video signal line RD, and when the respective signals are supplied to the auxiliary scanning signal line RL1, the auxiliary scanning signal line RL2 and the auxiliary scanning signal line RL3.

Embodiment 5.

Fig. 12(a) is a plan view showing another embodiment of the above-mentioned pixel of the liquid crystal display panel PNL.

In the same manner as the above-mentioned embodiment, one pixel is positioned between drain signal lines DL which are arranged close to each other and the pixel is provided with the pixel electrodes PX1, PX2, PX3 which are arranged in parallel to each other. However, this embodiment differs from the previous embodiments in that the liquid crystal display panel PNL includes gate signal lines GL1, GL2, GL3 for independently driving the respective pixel electrodes PX1, PX2, PX3 respectively.

That is, the pixel electrode PX1 is configured to receive the supply of the video signal from the drain signal line DL which is positioned at the left side of the pixel, for example, through the thin film transistor TFT1, while the thin film transistor TFT1 is turned on in response to the scanning signal from the gate signal line GL1. Further, the pixel electrode PX2 is configured to receive the supply of the video signal from the above-mentioned drain signal line DL through the thin film transistor TFT2, while the thin film transistor TFT2 is turned on in response to the scanning signal from the gate signal line GL2. Still further, the pixel electrode PX3 is configured to receive the supply of the video signal from the above-mentioned drain signal line DL through the thin film transistor TFT3, while

the thin film transistor TFT3 is turned on in response to the scanning signal from the gate signal line GL3.

Due to such a constitution, it is possible to reduce the number of wiring compared to the above-mentioned pixel constitution.

Fig. 12(b) is a timing chart in the reflection mode showing, in the liquid crystal display panel PNL having the pixels of the above-mentioned constitution, respective displays of the pixel electrode PX1, the pixel electrode PX2 and the pixel electrode PX3 when the video signal is supplied to the drain signal line DL, and when the scanning signal is supplied to the gate signal line GL1, the gate signal line GL2 and the gate signal line GL3.

The red display, the green display and the blue display are performed in a changed-over-manner on the pixel electrode PX1, the pixel electrode PX2 and the pixel electrode PX3 respectively along with the lapse of time. In this case, however, the liquid crystal display panel PNL is configured such that the black display is performed after the display in one pixel electrode is finished and before the display in the next pixel electrode is started.

That is, the scanning signal is simultaneously supplied to the respective gate signal lines GL1, GL2, GL3 when the black display is performed and the black is written in the whole screen at the time of sequentially changing over red, green and blue.

Due to such a constitution, it is possible to remove the charges of colors stored in the pixel electrodes PX1, PX2, PX3 so as to prevent color mixing.

Further, in performing such an operation, the respective gate signal lines GL of the liquid crystal display panel PNL may be sequentially scanned from above to below in the drawing. However, in this case, the display time of color differs between an upper portion and a lower portion of the screen. Accordingly, as shown in Fig. 12(c), it may be possible to use a case in which the respective gate signal lines GL are scanned from above to below in the drawing and a case in which the respective gate signal lines GL are scanned from below to above in the drawing in a mixed form alternately for every one frame or for every plural frames.

Due to such a constitution, it is possible to level the in-plane brightness thus reducing the display irregularities.

The above-mentioned respective embodiments may be used in a single form or in combination. It is because that advantageous effects of the respective embodiments can be obtained in a single form or synergistically.

Further, although an object into which the above-mentioned liquid crystal display device is incorporated is not limited, it is desirable that the liquid crystal display device is applied to a screen part of, for example, a PDA (Personal Digital Assistant) such as one shown in Fig. 12(a) or a mobile phone

such as one shown in Fig. 12(b). It is because that the PDA and the mobile phone are miniaturized and hence, there exist many opportunities that they are used outdoors and the ambient light such as sun beams can be used as the light source.

As can be readily understood from the foregoing explanation, according to the liquid crystal display device of the present invention, the liquid crystal display device has no mechanical operation mechanism and hence, it is possible to enhance the reliability and to realize the miniaturization of the liquid crystal display device.